upon an accurate definition, with a view to facilitate an appropriate denomination. According to this definition they are "Celestial bodies of a small or a very small size, which move in orbits of no very great excentricity round the sun, the planes of which may be inclined to the ecliptic in any angle whatsoever: their motion may be direct or retrograde; and they may or may not have very considerable atmospheres, or very small comas or nuclei."

Description of the Corundum Stone, and its Varieties, commonly known by the Names of Oriental Ruby, Sapphire, &c.; *with Observations on some other Mineral Substances. By the* Count de Bournon, *F.R.S.* Read March 25, 1802. [*Phil. Trans.* 1802, *p.* 233.]

In a former paper, printed in the Philosophical Transactions for the year 1798, Count de Bournon gave an analytical description of the crystalline forms of corundum from the East Indies and from China. From a note inserted at the beginning of the present communication, we learn, that the great number of specimens of that substance, since collected from different parts, chiefly of the East, have added so considerably to our knowledge relating to that subject, as to render it necessary not only to correct, but even, in many respects, to alter our opinion concerning it: and that hence, rather than create intricacy by introducing this additional knowledge in the form of a supplement, he had thought it expedient to collect all the information that could be obtained into one point of view, in hopes of delivering, in the present paper, with the addition of a chemical analysis which we are taught to expect from Mr. Chenevix, a complete mineralogical history of this curious substance.

The paper is prefaced by a short historical account of the opinions of former naturalists concerning the corundum stone, and its classification in the mineral system. The first of these, who derived their knowledge chiefly from lapidaries, had no hesitation in placing it among the gems, the hardest of which they distinguished by the epithet Oriental, and subdivided them according to their colours. Romé de Lisle was the first who deduced distinctive characters from the crystalline forms of the different sorts, rejecting the colour as a fallacious character. The first chemists who undertook to analyse this stone, thought themselves authorized to consider it as consisting of new elementary earths; but afterwards it was thought, and it appears now with much reason, to belong to the class of those stones which are chiefly, if not entirely, composed of argill. Werner at length also undertook the analysis; but he retrograded somewhat from what has been since found to be the truth, by placing it between pitch-stone and felspar. Abbé Hauy at length, recurring again to the crystalline form, placed it immediately after felspar, and before the Ceylonite; from both which, however, it differs widely, both by its hardness and specific gravity.

We are greatly indebted to the zeal and perseverance of our honourable member, Mr. Charles Greville, for a very ample collec-

tion of specimens of this stone, and of various other species which were long thought analogous, but are now found to constitute with it a genus of some extent. This substance, we are now told, presents itself to our senses, especially to our sight, under two very dissimilar appearances. The first is the original corundum imported under that name and also under that of adamantine spar. At times it is brought in irregular fragments, but often in crystals, which are generally of a pretty large size. Those of the other appearance are, in fact, the gems hitherto known by the names of Sapphire, Ruby, &c. Another distinction is next made, according to the texture or fineness of the grain of these stones; the former being called imperfect, and the latter, or the gems, perfect Corundum.

The author now enters into a minute account of the appearances and the principal properties of this substance. And first he treats of its *colour*. This, he tells us, is at best but an uncertain character in stones, but yet it may at times afford some secondary marks of distinction. The common or imperfect corundum varies, in this respect, according to the country where it is found. That from the Carnatic is of a grayish white, sometimes approaching to a pale green, and sometimes, though rarely, of a red or blue colour: that from China and Ava is generally of a dull green or brown colour; and that from the coast of Malabar appears of a reddish brown.

The perfect corundum which is found in Pegu and in Ceylon is either red, blue, or yellow. The former is the Oriental ruby; the blue is the sapphire; and the yellow the topaz. From a duly proportioned mixture of the blue and the red is produced the purple colour, which constitutes the Oriental amethyst. The union of the blue and yellow forms the green colour, which is proper to the Oriental emerald; and a larger proportion of yellow produces the colour proper to the chrysolite.

2. As to *transparency*, the crystals of corundum from the Carnatic, having usually rough surfaces, are of course very imperfectly diaphanous; but when broken, their fragments have generally a certain degree of semi-transparency: most of these fragments, when held up to the light, show a number of fissures in their substance, which in a great measure prevent the transmission of light. These fissures arise from a want of cohesion between all the parts of the crystalline laminæ. The red and blue corundum of the Carnatic has a greater degree of transparency than those of any other colour; the blue in particular having generally the preference in this respect.

3. In *hardness* the corundum comes next to the diamond; but this quality, with regard to intensity, differs greatly, according to the colour and degrees of purity of the specimens. The corundum of the Carnatic, when it is neither blue nor red, is less hard than any other sort; whilst the imperfect blue species exceeds all the other varieties of this kind in hardness,—such is its density that it will emit pretty bright sparks when struck with steel.

4. This substance, like quartz, becomes phosphorescent by collision. The crystals of a red colour, whether of the perfect or im-

perfect kind, will emit a light of a very deep fire-colour, similar to that of a red hot iron.

5. The specific gravity of this stone varies in all its different kinds. The means deduced from a great number of observations afford the following numbers.

Imperfect corundum 3931. Perfect corundum, in the instance of Oriental ruby, 3977; and of sapphire, 4158. The difference seems to be proportionate to the degree of perfection of the crystallization, and consequently of the transparency of the stone.

6. We come now to the most extensive and most elaborate section of the paper which treats of the *crystalline forms* of the different kinds of corundum. The primitive form of all the kinds, whatever be their degree of perfection, we are here told is a *rhomboid* slightly acute, the obtuse angles of the planes measuring 94°, and the acute ones 86°; and it is asserted, that whatever the form of an individual crystal may be, it may always, by dividing it according to the lately established rules of crystallography, be ultimately reduced to this rhomboidal form. The manner in which crystals deviate from their primitive form, by the substitution of planes for the angles, effected by the retreat of rows of molecules, which constitute the crystalline laminæ, is amply discussed in a note; and nine modifications are described, forming a great variety of prismatic, pyramidal, and other crystals, of which some idea can only be formed by an inspection of the figures that accompany the paper.

7. The next section treats of the *fracture and texture* of this stone. In general we are told that all the kinds have a lamellated texture, the layers being in a direction parallel to the faces of the rhomboid, and that they break in a direction parallel to those faces. The ease, however, with which these laminæ may be divided, differs greatly in the different varieties; and this is ascribed to the degree of force existing in the attraction of the molecules which compose these crystals, as well as to the perfect adhesion of the crystalline laminæ composed of those molecules at all points of their surface. This attraction and adhesion, it is thought, varies with the colour of the stone, the blue or sapphire possessing those qualities in the highest degree, which accounts for the fracture of this stone being often in a direction oblique, and even at right angles to the planes of the laminæ.

8. The 8th section contains some observations on the phænomena of light exhibited by this stone. The prismatic, as well as the pyramidal crystals of corundum, when their extremities are terminated by planes which are perpendicular to their axes, very frequently exhibit on these planes a changeable variety of colours, known by the name of *chatoyant*. This property is ascribed to the reflection of light in the small intervals which remain between the crystalline laminæ in those parts where these laminæ are not in perfect contact. It follows hence that the most compact sorts of corundum will not exhibit this appearance. To the same property is also ascribed that beautiful reflection of light in the form of a star of six rays, frequently pro-

duced in rubies and sapphires when cut in a particular direction. As to the manner of cutting these asteries, or star-stones, as they are usually called, it appears to be rather the effect of chance than of any determined theory. Some hints, however, are here given for the purpose, which chiefly recommend a proper attention to the primitive rhomboidal form of the crystal.

In the 9th section the author treats of the characters of the corundum afforded by chemical analysis; and here he anticipates the results of the investigation we are to be favoured with by Mr. Chenevix. These confirm what he has all along maintained in this paper of the identity of the several kinds of stones which he has classed under the name of Corundum.

The ingredients are uniformly found to be the same in all the species, differing only, and but in a small degree, in their proportions. The principal of these ingredients is argill or alumina, which, in the imperfect corundum from the Carnatic, Malabar, China, and Ava, consist of between $86\frac{1}{2}$ and 91 in 100 parts. In the sapphire it amounts to 92, and in the ruby to 90 hundredths. The other constituent parts are silica and iron; the former in the greatest proportion. Of the identity of stones which bear very different appearances, another example is here given in the instance of the felspar, reasons being assigned why some species of schorl, the adularia, and some other substances, ought to be classed with it.

The author proceeds next to consider the sort of corundum which does not exhibit the smallest rudiments of crystallization, and which mineralogists have agreed to distinguish by the name of *Compact Corundum*. It resembles, in many respects, a coarse jasper; but its much greater degree of hardness, and its much higher specific gravity, render its true nature easily distinguishable. It has a lamellated appearance. The red sort, in particular, gives pretty strong sparks when struck with steel. It is phosphorescent, like crystallized corundum. Its specific gravity is 3902.

Three sections treat next of the matrices of different sorts of corundum; which lead the author to dwell largely on a variety of substances which hitherto were thought to have no kind of affinity with this stone.

The first section treats of the matrix of imperfect corundum from the peninsula of India, chiefly from the Carnatic, and of the substances with which it is accompanied. This matrix, as far as our present knowledge extends, appears to be a stone of a particular nature; sometimes of a loose granulated texture, not unlike a coarse sandstone; and at other times of a closer grain, similar to the kind of marble known by the name of Coarse-grained Saline Marble: both kinds are of a pearly gray colour, sometimes slightly tinged with green, and have a degree of semi-transparency not unlike chalcedony. Their specific gravities are inferior to that of felspar. In this substance the crystals of corundum are imbedded, nearly in the same manner as those of felspar are dispersed in porphyry or certain granites. The accompanying substances are, 1. *Lamellated fragments*, not un-

like felspar or adularia, and partaking of many of the properties of corundum itself, and even of its crystallization. 2. *Fibrolites*, which are described as small masses frequently crystallized, but different in some respects from all other mineral substances hitherto known. 3. *Thallite*, or the Epidote of Abbé Hauy. This is minutely described in three different states. 4. *Hornblende*, which is most constantly and most abundantly contained in the matrix here treated of. 5. *Quartz, Talc, Mica, Steatite, Garnets, Zircon;* all which, though manifestly dispersed in this matrix, are yet less frequent. And lastly, the presence of *black Oxide of Iron* is likewise evident, though not in such large proportions as in the matrix of the imperfect corundum from China.

Section 2. Of the matrix of imperfect corundum from China, and the substances with which it is accompanied.—This matrix is totally different from the preceding one, being a granite rock, composed of an aggregate mixture of felspar, fibrolite, mica, and attractable black oxide of iron: but none of that particular substance which has been mentioned as forming the basis of the preceding matrix is here observed. The four substances above mentioned are unequally distributed throughout the mass; some pieces being composed almost entirely of only one of them, while in other pieces the substances are mixed together in different proportions, and sometimes in nearly equal ones.

Section 3. Of the matrix of perfect corundum from the Island of Ceylon, and the substances of which it appears to be composed.—The author, on this head, speaks with some diffidence, as the precious stones comprised under the denomination of this kind of corundum are selected by the inhabitants from the sands washed down by the rivers or rivulets of the island, and have seldom been brought to Europe in any kind of matrix. He gives us, however, a list of the substances which compose the sands that are sent to us from Ceylon; although he will not venture to assert positively that these substances really accompany the corundum when in its matrix. They are, 1. *Spinelle Ruby*, which generally composes nine parts in ten of the whole mass of this sand, but in such small crystals or fragments as to render them of little or no consequence in trade; owing, no doubt, to the selection made in India before it is sent over. The few of a tolerable size that have been obtained, are here described as to their crystalline form, their colours, their peculiar matrix, in some of which was found an iron ore hitherto unknown, while some of them appeared evidently to be masses of adularia. 2. *Tourmalin*, in the form of a very obtuse rhomboid, with several varieties deducible from this form, and of different colours. 3. *Ceylonite*, so called by M. la Matherie, but distinguished by the name of Pleonaste in the Mineralogy of the Abbé Hauy. This is likewise of a variety of crystalline forms and colours. 4. *Zircon*, which, next to the Spinelle, is the substance most frequently found in the sand of Ceylon, the crystals of which, though very small, are yet in general very perfect. And lastly, though their numbers be very insignificant, some small scattered

fragments of quartz, felspar, calcareous spar, a brownish-yellow mica, and particles of attractable oxide of iron.

The paper closes with some account of corundum, which, contrary to the received opinion, that this stone was only found in the East Indies, has been thought to exist in other parts of the world. The author dwells mostly upon the appearances of a stone he himself discovered in the mountainous parts of the Forez in France, and which the Abbé Hauy considers only as a species of felspar. The Count alleges his reasons for classing it with the perfect blue corundum, known by the name of Sapphire. As to various stones found in Germany, in the Isle of Tirree on the western coast of Scotland, on Chesnut-hill near Philadelphia, and elsewhere, which have by some been considered as corundum, the author cautions us against acquiescing in those assertions till more conclusive arguments shall appear in their favour.

Analysis of Corundum, and of some of the Substances which accompany it; with Observations on the Affinities which the Earths have been supposed to have for each other, in the humid Way. *By* Richard Chenevix, *Esq. F.R.S. and M.R.I.A.* Read May 20, 1802. [*Phil. Trans.* 1802, *p.* 327.]

After a detail of several unsuccessful attempts to analyse this stone, which on account of its great hardness is both difficult to pulverize and to be reduced by saline agents, we find an ample description of the process, which was attended with the desired success. A piece of corundum, weighing 100 grains, was made several times red hot, and plunged into cold water; it was then pounded, first in a steel, and next in an agate mortar, and thus reduced into an impalpable powder. This powder was by means of dilute muriatic acid cleared from the ferruginous particles which adhered to it from the steel mortar. It was then put into a platina crucible with 200 grains of sub-borate of soda, and the mixture was exposed for an hour or two to a violent heat: the glass produced by this fusion was in about twelve hours dissolved, by boiling it in a proper quantity of muriatic acid.

The silica might now have been separated by evaporating the whole to dryness, but it was thought preferable to get rid of all the salts contained in the liquor by a precipitation effected by means of an alkaline carbonate. The precipitate thus obtained was then redissolved in muriatic acid, and the silica was hence cleared by evaporation. The remaining liquor was afterwards boiled with potash, by which means the alumina was precipitated. It was then redissolved by the excess of potash, from which the earth was finally obtained by muriate of ammonia. A small proportion of iron was separated by muriatic acid. Both these earths being now washed and dried, were ignited, and thus the exact weight of each was accurately ascertained. The author paid particular attention to the silica produced in this process; as Mr. Klaproth, who had formerly analysed this stone, declares that he never found any of this ingredient.